CHARACTERIZATION OF GRAPHITE POLYURETHANES COMPOSITE FROM RENEWABLE BASED OILS

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DEDICATION

" Bonda , Ayahanda,
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ABSTRACT

This thesis aims to evaluate the characterization of graphite polyurethane composite from renewable based oils. Virgin cooking oil (VCO) as a renewable resource is the main substance in fabricating the renewable polyurethane (PU) and its graphite as called polyurethane graphite (PG). The fabricating sample have two methods that is open casting and heat press method. PU and PG with different percentage of graphite as filler were investigated for structural, morphological, physical and mechanical properties that going through a several testing including Optical Microscope (OM), Scanning Electron Microscope (SEM), Ultraviolet-visible (UV-Vis), Fourier Transform Infrared (FT-IR), Density Test, Tensile test and cross-link density. The renewable polyurethane is namely as PU and polyurethane graphite is namely as PG_2, PG_4, PG_6, PG_8, PG_{10} with subscript numbers indicate the weight loading of graphite content was varied in the renewable polyurethane from 2, 4, 6, 8, and 10wt%. The result of SEM and OM showed that the graphite particles are randomly distributed and homogeneously scattered well in the PU due to interconnected interface within the matrix of polymeric composites. UV- Vis technique is used to characterize the absorption, transmission and reflectivity of the PU and PG's otherwise the FT-IR is used for determine the composition and characterize the polymer structure of PU and PG's. As expected, the mechanical properties of composites proven that the addition of graphite can change the matrix properties of PU to improve modulus and consequent lowered the tan delta with respected of increasing the temperature. The calculated cross-linked density of PU and PG composites revealed the increment of graphite particle loading gives highest result of cross-linking and this is due to the PG_{10} is the highest graphite content and the highest value of storage modulus, highest value of tensile strength and the highest value of young modulus. Therefore, the result shows the renewable polymer graphite composite is suitable to be used in various composites applications.

ABSTRAK

Tesis ini bertujuan untuk menilai pencirian komposit polimer grafit dari minyak yang boleh diperbaharui.Minyak masak dara (VCO) sebagai sumber yang boleh diperbaharui adalah bahan utama dalam pembuatan polimer yang diperbaharui (PU) dan dicampurkan grafit yang disebut grafit polimer (PG). Sampel fabrikasi mempunyai dua kaedah iaitu kaedah tuangan terbuka dan tekanan panas. PU dan PG dengan peratusan grafit yang berbeza diuji untuk sifat struktur, morfologi, fizikal dan mekanikal yang melalui beberapa ujian termasuk Mikroskop Optik (OM), Mikroskop Elektron Pengimbasan (SEM), Ultraviolet-terlihat (UV-Vis), *Fourier Transform Infrared* (FT-IR), *Density Test*, *Tensile test* dan *cross-link density*. Polimer yang boleh diperbaharui adalah seperti PU dan grafit polimer adalah seperti PG_2, PG_4, PG_6, PG_8, PG_{10} dengan nombor menunjukkan kandungan grafit berbeza dalam polimer yang boleh diperbaharui dari 2, 4, 6, 8, dan 10 wt% . Hasil SEM dan OM menunjukkan bahawa zarah grafit tersebar secara rawak dan tersebar secara homogen dengan baik di PU kerana antara muka yang saling berkaitan dalam matriks komposit polimer. Teknik UV- Vis digunakan untuk mencirikan penyerapan, transmisi dan pantulan PU dan PG sebaliknya FT-IR digunakan untuk menentukan komposisi dan mencirikan struktur polimer PU dan PG. Seperti yang dijangkakan, sifat mekanik komposit membuktikan bahawa penambahan grafit dapat mengubah sifat matriks PU untuk meningkatkan *modulus* dan seterusnya menurunkan *tan delta* dengan peningkatan suhu. Ketumpatan silang gabungan komposit PU dan PG mengungkapkan peningkatan pemuatan zarah grafit memberikan hasil penghubung silang tertinggi dan ini disebabkan PG_{10} adalah kandungan grafit tertinggi dan nilai *modulus* penyimpanan tertinggi, nilai kekuatan tegangan tertinggi dan nilai tertinggi *modulus muda*. Oleh itu, hasilnya menunjukkan komposit grafit polimer yang boleh diperbaharui sesuai digunakan dalam pelbagai aplikasi komposit

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVATIONS

Cm	-	Centimetre
Cm-1	-	Per Centimetre
°C	-	Degree Celsius
°C/min	-	Degree Celsius Per Minute
E’	-	Storage Modulus
E”	-	Loss Modulus
MPa	-	Mega Pascal
mL	-	Millilitre
Mm	-	Millimeter
Tg	-	Glass Transition
Ve	-	Cross-linked Density
wt%	-	Percentage Weight Loading
%	-	Percentage
δ	-	Delta
µm	-	Micrometre
ASTM	-	American Society for Testing Materials
UTHM	-	Universiti Tun Hussein Onn Malaysia
SEM	-	Scanning Electron Microscope
OM	-	Optical Microscope
FT-IR	-	Fourier Transform Infrared Spectroscopy
UV-Vis	-	Ultraviolet Visible
DMA	-	Dynamic Mechanical Analysis
H_2O	-	Water
O_2	-	Oxygen
CO_2	-	Carbon dioxide
OH	-	Hydroxyl group
C-C	-	Carbon to carbon

MDI	-	Methylene Diphenyl Diisocyanate
TDI	-	Toluene Diisocyanate
HMDI	-	Hexamethylene diisocyanate
PU	-	Renewable Polyurethane
PG	-	Polyurethane graphite
VCO	-	Virgin Cooking Oil
HDPE	-	High Density Polyethylene
PLA	-	Polylaticacid
PP	-	Polypropylene

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

A sustainable natural resource, or renewable natural resource, is any common asset that is exhausted at a rate equivalent to or not as much as the rate at which it is renewed. As a result, renewable natural source is hypothetically endless insofar as sound, sustainable management practices are applied (Eric L. Taylor, 2013).

Recently, based on the increasing interest, the development of more environment-friendly polymer products have become popular. According to (Greet Bleys, 2015), the word "biopolymers" is defined as a polymeric material with at least a significant part of it is made out of a biological component. "Biological" means products by living organisms not produced from petroleum. In recent years, research and development of biopolymers has gained momentum through the principles of green chemistry and the increasingly adapted sustainability of the sector.

Polymers with ester-bonding at the macromolecular backbone are a highly attractive group of biodegradable synthetic plastics families. To use this compound, virgin cooking oil is a laminating material for polymer synthesis. The use of lignocellulose biomass, such as the stabilizer for palm oil in the polymer matrix, offers positive environmental benefits in terms of final availability, use of raw materials and strong mechanical properties. The main advantages of lignocellulose biomass are high availability, low energy consumption, low cost, low density, high specificity and modulus, relatively reactive surface that can be used to group specific groups, easily recycled by burning cellulose-containing composites (Lee *et al*., 2014; Ribeiro Da Silva *et al*., 2013)..

PU (polyurethane) is the most importance one which extensively used and of versatile nature, comprises hard (isocyanate) and soft (polyols) segment (Zhang *et al.*, 2017). PU can be design according to user needs, yet under harsh condition, PU itself fails to give satisfactory thermal, mechanical and electrical performance (Almeida Junior , 2013; Plyushch *et al.*; 2016; Wu *et al.*, 2018). Hence, under hash environmental condition, PU need to provide such good condition to induce such structural properties through their blending and composite formation. It has been observe that the synergistic effect between carbon-based filler and insulating PU matrices enhance the proaccessibility, stability, solubility, thermal, mechanical, electrical and optical properties (Sattar *et al.*, 2014).

In this research, a study is conducted on the epoxides that is from virgin cooking oil (VCO) to derive the chemical reaction to form polyurethane. Besides using a biomass from virgin cooking oil (polyurethane), to form a good polymer composite product, a filler is added. A filler is used to improve certain characteristics and reduce material cost. Besides that, the filler has advantages such as unlimited sources, low cost, easy-to-perform chemical and mechanical reactions and the most important is that it is not harmful to health (Muller, K. et al., 2017).

In this study, graphite is used as a filler. Graphite is one of three forms of crystalline carbon; the other two are diamond and fullerenes. Graphite occurs naturally in metamorphic rocks such as marble, schist and gneiss. It is a soft mineral, also known by the names of black lead, plumbago and mineral carbon. The word graphite is derived from the Greek word “graphein”, which means “to write”. It has a Mohs hardness of 1 to 2 and exhibits perfect basal cleavage. Depending upon the purity, the specific gravity is 2.20 to 2.30. The theoretical density is 2.26 grams per cubic centimeter. It is grey to black in colour, is opaque and has a metallic lustre. It is flexible but not elastic. Graphitisation of naturally occurring organic carbon may occur at temperatures as low as 300 ºC to 500 ºC or as high as 800 ºC to 1,200 ºC, such as when an igneous intrusion contacts a carbonaceous body (Rustu S. Kalyoncu, 2000).

The focus of this study is to evaluate the mechanical characteristics based on Dynamic Mechanical Analysis and correlation properties of tensile strength of neat polyurethane (PU) and polyurethane graphite (PG) thin films from virgin cooking oil.

1.2 Problem Statement

Over the past decade, polymers have attracted significant international interest as they are likely to solve a variety of industrial problems in nanotechnology and electronics. Dozens of companies are currently planning and selling polymer units around the world for various emerging markets. Some research centers also improving and develop polymer thin films, basic polymer studies, and polymer preparation and application techniques. More recently, increased attention has been given to thin-film polymers, which play an increasingly important role in the application of coatings, adhesives and lithography technology to organic light-emitting diodes and various materials-based tools such as sensors and detectors (Abbass A. Hashim, 2010) .

Today's world is focusing on renewable sources to replace fossil fuels. The replacement of fossil fuels is due to the use of fossil fuels as a source of energy for heat, electricity and transport have been identified as one of the main causes of global warming, as indicated by the change climate change in the world. Therefore, in order to reduce the cause of global environmental problems and promote the efficiency of energy, thermochemical conversion such as the dilution process is one of the methods used to generate renewable resources. The availability of new technologies is absolutely necessary to transform this sustainable source of palm oil into a wide variety of value-added products that will save money and reduce processing costs (Awalludin *et al*., 2015; Sulaiman *et al*., 2010).

A component's mechanical and physical properties deteriorate especially when certain substances are used in the polymer product. The strong material structure, the material properties can be improved by adding a filler such as graphite. In recent years, new technologies in processing and treatment have expanded the use of natural graphite in battery applications. Graphite for these applications is purified to 99.9% carbon. Most new uses for graphite products are being developed through advances in graphite thermal technology (Schulz *et al*., 2017).

In this case, the problem is to find new ideas and new formulas in automotive production, packaging or construction applications. according to existing products, automotive applications such as cushions, car dashboards, door panels and engine covers are manufactured using natural filler or fiber-based and petroleum-based (Awalludin *et al.*, 2015; Rupani *et al.*, 2013). The ability to refine and modify graphite and carbon products will be the key to future growth in the graphite industry. Innovative refining techniques have enabled the use of improved graphite in friction materials, electronics, foil and lubrication applications (Hand, l997). Some of the new application areas include electrically conductive asphalt for heated runways at airports and roadway bridges. With its low specific gravity, refractoriness and corrosion resistance, graphite is critical for many industrial applications, such as dies for continuous casting, rocket nozzles and heat exchangers for the chemical industry. Meanwhile, in this research, a liquid biopolymer is used by adding a crosslinking agent as a thin film biopolymer to replace a commercial material.

1.3 Objectives of Study

The objectives of this research to analyse the mechanical properties of polyurethane (PU) and polyurethane graphite (PG) thin films. The PU and PG are tested to achieve specific objectives in support of the following goals:

i. To evaluate the physical, morphological structure and tensile properties of polyurethane thin film (PU) and polyurethane graphite thin films (PG).
ii. To determine the effect of graphite content on thermo mechanical properties of polyurethane thin film.
iii. To assess the effect of fabrication method of PU and PG, using open casting and heat press method on physical, tensile and thermo-mechanical properties of PU and PG's.

1.4 Research Scope

The research was conducted at Sustainable Polymer Engineering Laboratory, Advanced Manufacturing and Material Center (SPEN-AMMC) Universiti Tun Hussein Onn Malaysia (UTHM) and focuses on:

1. Fabricate the samples of PU and PG thin films using open casting and heat press method with the addition of 2%, 4%, 6%, 8% and 10% of graphite.

2. The physical characterization for determine the properties of PU and its composite are listed below.

    a) Visual assessment of PU and PG
    b) Density test
    c) Optical microscope (OM)
    d) Scanning Electron Microscope (SEM)
    e) Fourier transform infrared spectroscopy (FTIR)
    f) UV-Vis spectroscopy

3. The Mechanical characterization for determine the properties of PU and its composites are listed below

    a) Tensile test
    b) Dynamic mechanical analysis (DMA)

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Production of new material through physical blending various polymers has become increasingly popular. This is because a number of advantages increase such as getting the properties required by the end use, the ability to increase certain attributes and advantages obtained when used in service conditions. However, the economic advantage obtained through this technology is low cost as key factors for their development. Since Malaysia is the one country that obtains technology in low cost, researcher are motivated to study and making finding in substitute petroleum-based fossil fuel product to effective utilization of biomass. In this study, the polymer is used as a material substitute. Basically, the filler is added to the polymer to improve certain characteristics and reduce material costs or to achieve both objectives simultaneously (N. Saba et al., 2014).

This chapter provides a literature review of some significant contribution which directly related to explanations relevant to the development of renewable polymer from virgin cooking oil for stress, strain and damping characteristics also the testing method and equipment used for evaluating the thin films. Establishing a framework for the present study, the analyses, the useful reviews and explanations of the research information from previous studies were used as a guideline to complete this research project.

REFERENCES

A. Ezenwa. (2012). Effect of Film Thickness on the Transmittance of Chemical Bath Fabricated Cds Thin Film

A. B. Cherian, L. A. Varghese, E. T. Thachil, (2007).European Polymer Journal 43, 1460.

A. V. Shenoy and D. R. Saini. (1996). “Thermoplastic Melt Rheology and Processing”, Marcel Dekker Inc., New York.

A. Abbass Hashim (2010), Polymer Thin Films . Publish by In-Tech Olajnica 19/2, Vukovar, Croatia.

Abdel Hakim, A.A., Nassar, M., Emam, A. & Sultan, M. (2011). Preparation and Characterization of Rigid Polyurethane Foam Prepared from Sugar-cane bagasse Polyol. *Material Chemistry and Physics. 129, 301-307.*

Abdullah Al Ashraf. (2014). FTIR & UV-VIS Analysis of Polymer Sample.

Aharon, Refael, 2014. Manufacturing materials from waste water effluent.

Alexandra Bruce,Karen DeRocher, Ibrahim El Hedok, Eliot Fair, Adam Ten Napel, 2017 (injection molding and tensile testing of assorted polymers. https://sites.google.com/site/mse553g6lab7/lab-introduction

Ana Dotan, (2014). Handbook of Thermoset Plastics. Elsevier Inc.

Anandh balakrishan, mrinal c. saha.2009. Dynamic mechanicalbehavior of thermoplastic thin polyurethane films.

Anika Zafiah, Nur Munirah, M.F.L Abdullah, M.Izzul Faiz Idris. (2015). Graphite/Bio-based Epoxy Composites: Structural, Optical And Electrical Properties. Applied Mechanical and Materials vols: 799-800 pp 153-157

Anika Zafiah, Nur Munirah, M.F.L Abdullah, M.Izzul Faiz Idris. Graphite/Bio-based Epoxy Composites: The Mechanical Properties Interface (2015). Applied Mechanical and Materials vols:799-800 pp 115-119.

Anika Zafiah, Nur Munirah, M.F.L Abdullah. (2015). Interconnected Interface Enhance Electrical Properties of Graphite in Bio-based Epoxy from Insulating to Conductor Composites. Indian Journal of Science and Technology vol 8(17). IPLO159.

Anil Barak, V yom Deep Gangwar and S K Shukla (2018). Development and characterization of polyvinyl chloride-graphite membrane.

Anuar & Zuraida, 2011. “Thermal Properties of Injection Moulded Polylactic Acid – Kenaf Fibre Biocomposite H. Anuar * and A. Zuraida.” 6(1): 51–57.

Almeida Junior, J. H. S. (2013). Castor oil and Commercial Thermoplastic Polyurethane Membrnes Modified with Polyaniline : A Comparative Study. Materials Research, 16 (4), 860-866.

Aravind K. U., G. Rajendra, Prakash S T and Shivraj J.(2017) Mechanical Characterisation of Polyamide 66/Graphite Nanocomposites. International Journal of Materials Science ISSN 0973-4589 Volume 12, Number 3 , pp. 411-420.

Avgerinos GC, Wang DIC (1983).Selective delignification for fermentation of enhancement. Biotechnol Bioeng 25:67–83.

Awalludin, M. F., Sulaiman, O., Hashim. R., & Nadhari, W. N. A. W. (2015). An overview of the oil palm industry in Malaysia and its waste utilization through thermochemical conversion, specifically via liquefaction. *Renewable and Sustainable Energy Reviews, 50, 1469-1484.*

AZoM, 2002. Graphite C, Classification, properties, and application of graphite. AZO materials website https://www.azom.com/article.aspx?ArticleID=1630.

Badri, K. H Mohd Dawai, L. I., & Abd Aziz, N. A (2013). Rigid polyurethane foam from glycolysed polyethylene terephthalate dissolved in palm-based polyol. Sains malaysiana, 42(4), 449-457.

Baez-vasquez, marco A, Putilin, Betty, 2015. Integrated process extraction of pineapple biomass into fibers and natural products.

Balram Tripathi, Kamlendra Awasthi, Vaibhav Kulshrestha, Anshu Sharma,Shweta Agrawal, Sumit Kumar,S.S Sharma, Ankita Garg, M.Singh and Y.K.Vijay, (2010). Optical and Dynamic Mechanical Characterization of Thin Film Polymer Nanocomposites. International Journal Of Modern Physics B. Vol.24 Nos 1&2 57-63.

Batallas, M., Yih, H. & Singh, P. (2006).Determining The Performance of Polyurethane Foam Pipe Insulation for High Temperature Service. pp. 1-18.

Bastiurea, M., Rodeanu, M. S., Dima, D., Murarescu, M., & Andrei, G. (2015). Thermal and Mechanical Properties of Polyester Composites With Graphene Oxide and Graphite. *Digest Journal of Nanomaterials and Biostructures*, 10(2),521-533.

Behr, A., Westfechtel, A., & Gomes, J. P. (2008). Catalytic Processes for the Technical Use of Natural Fats and Oils. *Chemical Engineering & Technology*. Vol 31(5), pp. 700-714.

Boerio. F.J. (2002), measurement of the chemical characteristic of polymer and rubbery by vibrational spectroscopy Vol.4 pp2419-2536.

Booklet “A Beginner’s Guide” Perkin Elmer, 2008).

Bower D.I and Madam W.F. (1989). The vibrational spectroscopy of polymers, Cambridge University Press.

Brinchi, L., Cotana, F., Fortunti, E., Kenny, J.M (2013). Production of nanocrystalline cellulose from lihnocellulosic biomass: technology and application. Carbohydrate polymer, 94, 154- 169.

C. Becker, P. Mueller, H. Schmidt, SPIE, 3489, 88(1998).

Carrio, C. S., Fraga, T., & Pasa, V. M. D. (2016). Production and characterization of polyurethane foams from a simple mixture of castor oil, crude glycerol and untreated lignin as bio-based polyols. *European Polymer Journal*, *85*, 53–61.

Caliari, Í. P., Barbosa, M. H. P., Ferreira, S. O., & Teófilo, R. F. (2017). Estimation of cellulose crystallinity of sugarcane biomass using near infrared spectroscopy and multivariate analysis methods. Carbohydrate Polymers, 158, 20–28.

Capanema, Ewellyn A, Balakshin, Mikhail Y 2014.High Purity Lignin, Lignin Compositions, and Higher Structured Lignin.

Cernohous, Jeffrey J, Winsness, David J (2015) Thermoplastic Compositions Containing Bio-Based Materials And Processes For Forming An Article Therewith

Chalmers J.M Hannah R.W and Mayo D.W (2002).spectra-structure correlation polymers in handbook of vibrational spectroscopy.

Chalmers J.M (2000). Infrared spectroscopy in analysis of polymers and rubbers in encyclopedia of analytical chemistry Vol.9 pp 7702-7759.

Chandra RP, Bura R, Mabee WE, Berlin A, Pan X, Saddler JN (2007).Substrate pretreatment: the key to effective enzymatic hydrolysis of lignocellulosics? Adv Biochem Eng Biotechnol 108:67–93.

Chen, S., Wang, T., Wang, Q., & Pei, X. (2011). Damping Properties of Polyurethane / Epoxy Graft Interpenetrating Polymer Network Composites Filled with Short Carbon Fiber and Nano-SiO2. *Journal of Macromolecular Science*, Part B, 50(5);931-41.

Cinelli, P., Anguillesi, I., & Lazzeri, A. (2013). Green synthesis of flexible polyurethane foams from liquefied lignin. *European Polymer Journal, 49(6),* 1174–1184.

Chen GQ, Martin KP (2012). Plastic derived from biological sources: Present and Future, a technical and environmental review: Chem Rev 112: 2082-2099.

David R. Borst and David W. Pratt. Toluene: Structure, dynamics, and barrier to group rotationin its electronically excited state. A route to Journal of Chemical Physics, Volume 113, No 9

D. Chattopadhyay and D. C. Webster. 2009.Thermal stability and flame retardancy of polyurethanes, Prog. Polym. Sci, 34, 1068–1133.

Dongu Cai, Kamal Yusof, Mo Song (2009). The Mechanical Properties and Morphology of a Graphite Oxide Nanoplatelet/Polyurethane Composites. Volume 20, Number 8.

Dongu Cai, Kamal Yusof, Mo Song. (2009). The Mechnical Properties and Morphology of Graphite Oxide Naniplatelet/Polyurethane Composites. Volume 20, Number 8.

Dr Bassam Ibrahim Khalil (2008), Intriduction of Polymers : Medical and Biological Polymers

Dr Hanna J. Alshimary (2011).Polymer science lecturer 1 second class.

Dr. Ramesh B. Polymer matrix composites. Slide share. 2011.

Dworakowsa, S., Bogdal, D., Prociak, A., (2012). Microwave-assisted synthesis of polyols from rapeseed oil and properties of flexible polyurethane foams. Polymers 4, 1462-1477.

E. Delebecq, J.-P. Pascault, B. Boutevin and F. O. Ganachaud. 2012. On the versatility of urethane/urea bonds: reversibility, blocked isocyanate, and non-isocyanate polyurethane, Chem. Rev., 113, 80–118, DOI:

Ehrburger-Dolle, Françoise, Manuela Hindermann-Bischoff, Erik Geissler, Cyrille Rochas, Françoise Bley, and Frédéric Livet. (2000)."Role of fractal features in the structure-property relationships of carbon black filled polymers." MRS Online Proceedings Library Archive 661.

Fengel D, Wegener G (1984) Wood chemistry, ultrastructure, Reactions. Walter de Gruyter, Berlin.

Foening J.L (1999).Spectroscopy of polymers.

Gama, N. V., Soares, B., Freire, C.S.R., Silva, R., Neto, C.P., Barros- Timmons, A., Ferreira, A. 2015. Bio-based polyurethane foams toward applications beyond thermal insulation materials and design 76,77-85.

Gandini, A., & Lacerda, T. M. (2015). From monomers to polymers from renewable resources: Recent advances. Progress in Polymer Science, 48, 1–39.

Gobi and Vadivelu, V. M. (2013). By-products of palm oil mill effluent treatment plant- Astep towards sustainability. *Renewable and Sustainable Energy Reviews, 28, 788-803.*

Greert Bleys, (2015). Technology watch : Biopolymers

Griffiths, P. and De Haseth, J. (2007). Fourier transform infrared spectrometry.

Gulmine, J., Janissek, P., Heise, H. and Akcelrud, L. (2002). Polyethylene characterization by FTIR. Polymer Testing, 21(5), pp.557--563.

Hoboken, N.J.: Wiley-Interscience. H. Gu, (2009). Materials and Design 30, 2774.

H. Ulrich, (1996). Chemistry and technology of isocyanates, Wiley.

Hasirci, V., Yilgor, P., Endogan, T., Eke, G., & Hasirci, N. (2011). Polymer Fundamentals: Polymer Synthesis. Comprehensive Biomaterials. Vol. 1, pp. 349-371.

Hassan, N. N. M., & Rus, A. Z. M. (2013). Influences of thickness and fabric for sound absorption of biopolymer composite. *Applied Mechanics and Materials*, *393*, 102–107.

Hassan, N.N.M., Rus, A.Z.M., Nurulsaidatulsyida, S., Mohid, S.R. 2013. “Acoustic study based on sustainable green polymer treated with H2O,” Adv. Mater. Research, vol. 748, p. 281-285.

He. J.Y, Zhang. Z.L, Kristiansen, H. Redford, K. Fonnum, G. Modahl, G.I. Crosslinking Effect on The Deformation and Fracture of Monodisperse Polystyrene-co-divinylbenze Particles. Express Polym. Lett. 7, 365-376. 2013.

Hejna, A., Kirpluks, M., Kosmela, P., Cabulis, U., Haponiuk, J., & Piszczyk, Ł. (2017). The influence of crude glycerol and castor oil-based polyol on the structure and performance of rigid polyurethane-polyisocyanurate foams. Industrial Crops and Products, 95, 113–125.

Helen M. Herring, (2003). Characterization of thin film polymers through dynamic mechanical analysis and permeation.

Hendricks AT, Zeeman G (2009). Pretreatments to enhance the digestibility of lignocellulosic biomass. Bioresour Technol 100:10–108.

Henry M. Sayre (2005), Writing about Art (Upper Saddle River, NJ: Prentice Hall) 58.

Hepburn, C. (1982). Polyurethane Elastomers, Applied Science Publishers, London and New York.

Hosseini, S. E., Wahid, M. A., & Ganjehkaviri, A. (2015). An overview of renewable hydrogen production from thermochemical process of oil palm solid waste in Malaysia. Energy Conversion and Management, 94, 415-429.

Huang, C.-L., Lou, C.-W., Liu, C.-F., Huang, C.-H., Song, X.-M., & Lin, J.-H. (2015).Polypropylene/Graphene and Polypropylene/Carbon Fiber Conductive Composites: Mechanical,Crystallization and Electromagnetic Properties. Applied Sciences, 5(4), 1196–1210.

Ismail Ibrahim Marhoon. (2017). Mechanical and Physical Properties of Polyurethane Composites Reinforces With Carbon Black N990 Particles. International journal of scientific & technology research volume 6, issue 08.

Jasmine Staggers. 2017. Market Research of Global Amorphous Graphite Market 2018 Fuctional Outlook, Company Profiles, Analysis - 2025. http://marketresearche.blogspot.com/2017/11/global-amorphous-graphite-market-2018.html

Jassim Mohammed Salman. 2015. Studying Some Properties of Unsaturated Polyester Composite Reinforced by Carbon Black, Particulate Journal of Babylon University, Engineering Sciences, No.(2),Vol.(23).

J. H. Li, J. Li and M. Li, 2007 Preparation of expandable graphite with ultrasound irradiation”, *Materials Letters* 61, pp. 5070–5073.

Jinghuai Zhang, Xiaodong Niu, Xin Qiu, Ke Liu, Changming Nan, Dingxiang Tang and Jian Meng. (2007). Effect of yttrium-rich misch metal on the microstructures, mechanical properties and corrosion behavior of die cast AZ91 alloy. Journal of Alloys and Compounds.

John O. Akindoyo, M.D.H, Beg, Suriati Ghazali, M.R.Islam, Nitthiyah Jeyaratnam, A.R. Yuvaraj, (2016) Polyurethane types, sysnthesis and applications.

John Wiley and Sons, 2015). Dynamic mechanical analysis in the analysis of polymers and rubbers.

Junhua Zhao, Peishi Yu and Shuhong Dong. The Influence of Crosslink Density on The Failure Behavior in Amorphous Polymers by Molecular Dynamics Simulations. Materials, 9, 234. 2015.

K. M. Zia, S. Anjum, M. Zuber, M. Mujahid and T. Jamil, (2014) Synthesis and molecular characterization of chitosan based polyurethane elastomers using aromatic diisocyanate, Int. J. Biol. Macromol, 66, 26–32

Kamweru, P Kuria et al. 2014. "UV Absorption and Dynamic Mechanical Analysis of Polyethylene Films." 9(24): 545–55.

Kampf, G.,(1986). Characterization of Plastics by Physical Methods, Experimental Techniques and Practical Application. Munich: Hanser

Karak, N. (2012). Vegetable oil-based polymers properties, processing and applications. Woodheads Publishing in Materials.

Kenan, W.M., 1984, Economics of graphite. Society of Mining Engineers. American Institute of Mining, Metallurgical, and Petroleum Engineers.Preprint no. 84-300, 3 p.

Kim, S. H., Kim, B. K., & Lim, H. (2008). Effect of isocyanate index on the properties of rigid polyurethane foams blown by HFC 365mfc. *Macromolecular Research, 16(5)*, 467–472.

Kong, S. H., Loh, S. K., Bachmann, R. T., Rahim, S. A., & Salimon, J. (2014). Biochar from oil palm biomass: A review of its potential and challenges. *Renewable and Sustainable Energy Reviews, 39, 729-739.*

Kormin, S., Rus, A.Z. M., & Azahari, M. S. M. (2017). Preperation of Polyurethane Foams Using Liquefied Oil Palm Mesocarp Fibre (OPMF) and renewable monomer from waste cooking oil, *IOP proceeding,060006.*

Kormin, S., Rus, A.Z.M., (2017). Preparation and Characterization of Biopolyol From Liquefied Oil Palm Fruit Waste : Part1 882, 108-112.

Klempner, D., & Sendijarevic, V. (2004). *Polymeric Foams and Foam Technology*. 2nd .ed. Munich: Hanser.

Kwasi Poku, (2002), Small-scale palm oil processing in Africa.

Labcompare.com, (2014). Infrared Spectroscopy (IR / FTIR) - Labcompare. [online] Available at: http://www.labcompare.com/Spectroscopy/165-Infrared-Spectroscopy-IR-FTIR [Accessed 26 Oct. 2014].

Latif, N.A., Rus, A.Z.M. & Ghani, M. (2014). Influence of Hot Compression Moulding of Particulate Biopolymer and Their Sandwich Layups for Sound Absorption Characteristic. *Applied Mechanics and Materials*. Vol 465, pp. 1044-1048.

Lee, A. (2014) Sysnthesis of polyurethane from one hundred percent sustainable natural materials through non-isocyanate reaction, Master thesis.

Lee, T., Zubir, Z. A., Jamil, F. M., Matsumoto, A., & Yeoh, F. Y. (2014). Combustion and Pyrolysis of Activated Carbon Fibre From Oil Palm Empty Fruit Bunch Fibre Assisted Through Chemical Activation With Acid Treatment. Journl of Analytical and Applied Pyrolysis, 11(1), 408-418.

Lligadas, G., Ronda, J. C., Gali, M., & Cdiz, V. (2013). Renewable polymeric materials from vegetable oils: A perspective. Materials Today, 16(9), 337–343.

Liu, X., Zhu, X., & Pan, D. (2018). Solutions for the problems of silicon-carbon anode materials for lithium-ion batteries. *Royal Society open science*, *5*(6), 172370. doi:10.1098/rsos.172370.

Liu K, He B, Qian L and Li J 2014 Conducting Graphite / Cellulose Composite Film as a Candidate for Chemical Vapor-Sensing Material 9 5279–89

Luo, X., Mohanty, A., & Misra, M. (2013). Lignin as a reactive reinforcing filler for water-blown rigid biofoam composites from soy oil-based polyurethane. Industrial Crops and Products, 47, 13–19.

Luo, X., & Li, Y. (2014). Synthesis and Characterization of Polyols and Polyurethane Foams from PET Waste and Crude Glycerol. *Journal of Polymers and the Environment*, *22(3), 318-328.*

M D S Hajar, A G Supri, M P M Hanif, M I M Yazid (2017). Effect of graphite loading on the electrical and mechnical properties of poly (Ethylene Oxide) / poly (Vinyl Chloride) polymer films

M. Aurilia, L. Sorrentino, S. Iannace,(2012). European Polymer Journal 48, 26.

M. Ionescu, (2007). Chemistry and technology of polyols for polyurethanes, Rapra Technology, Shrewsbury, UK, Polymer International, 2007, vol. 56.

M. R. Anika Zafiah, (2009) “Degradation studies of polyurethanes based on vegetables oils, Part I; Photodegradation”, Progress in Reaction Kinetic and Mechanism, 33: 391-363.

M. R. Islam, M. D. H. Beg and S. S. Jamari (2014). Development of vegetable-oil-based polymers, J. Appl. Polym. Sci., 2014, 131(18), 40787–40790, DOI.

M. Bastiurea, M.S.Rodeanu, D.Dima, M.Murarescu, G.Andrei (2015). Thermal and mechanical properties of polyester composites with graphene oxide and graphite. Digest Journal of nanomaterials and Biostructures. Vol 10, no.2 p.521-533.

Mario Filipe Lima do Vale, (2015) Lignopolyol based one-component polyurethane foams. Master thesis.

Menard, K.P., (1999) Dynamic Mechanical Analysis: A Practical Introduction. Boca Raton: CRC Press LLC.

Miao, S., Wang, P., Su, Z., & Zhang, S. (2014). Vegetable-oil-based polymers as future polymeric biomaterials. *Acta Biomaterialia, 10(4),* 1692–1704.

Michele Sepe. Materials: Perfomance in polyethylene: density matters (2014) https://www.ptonline.com/articles/materials-performance-in-polyethylene-density-matters

Midgett, J. S. (2008). Assessing a hydrothermal liquefaction process using biomass feedstocks. Master thesis

Mohid, S.R., Rus, A.Z.M., Harun, N.H. 2013. “Influence of bio polymer composites as heat absorption coating,” Applied Mechanics and Materials, vol. 315, p. 404-407.

M. Torres Jessica, Chengqing Wang, E.Bryan Coughlin, John P.Bishop (2011). Influence of Chain Stiffness on Thermal and Mechanical Properties of Polymer Thin Film.

Muhammad Zulkhairi bin Jailani. Dynamic Mechanical Thermal Analysis Of Wood Polymer Composite Upon Ultra Violet Irradiation Exposure. (2018). Thesis PSM.

Naheed Saba, Paridah Md Tahir and Mohammad Jawaid. A Review on Potentiality of Nano Filler/Natural Fiber Filled Polymer Hybrid Composites.Polymers 2014, 6, 2247-2273; doi:10.3390/polym6082247.

Nadia. Palm oil and its importance to national development. https://www.slideshare.net/DiaNadia4/palm-oil-46924062.

Nagendran, B.; Unnithan, U. R.; Choo, Y. M.; Sundram, Kalyana (2000). "Characteristics of red palm oil, a carotene- and vitamin E–rich refined oil for food uses". *Food and Nutrition Bulletin*. **21** (2): 77–82.

Ng, W. S., Lee, C. S., Chuah, C. H., & Cheng, S. F. (2017). Preparation and modification of water-blown porous biodegradable polyurethane foams with palm oil-based polyester polyol. *Industrial Crops and Products, 97*, 65–78.

Nieto, E. D.R. (2011). New Polyurethane from Vegetable Oil-Based Polyol. University Rovira. PhD Thesis.

Nur Munirah Abdullah, M. Saddam Kamarudin, Anika Zafiah M.Rus, M. F. L. Abdullah. 2017. Preparation of Conductive Polymer Graphite (PG) Composites.

Nur Munirah Abdullah, Anika Zafiah M. Rus and M. F. L. Abdullah, 2015. Synergistic Influence Of Graphite On Biopolymer Composites Properties, *Jurnal Teknologi (Sciences & Engineering) 77:32 (2015) 11–19.*

O. Bayer, Das (1947). di-isocyanat-polyadditionsverfahren(polyurethane), Angew. Chem, 59(9), 257–272, DOI:

O. Bayer, (1947). Polyurethanes, Mod. Plast. . 24, 149–152

P. Bajpai (2016). Pre-treatment of Lignocellulosic Biomass for Biofuel Producution.

P. Ramalingam, S. T. Pusuluri, S. Periyasamy, R. Veerabahu, and J. Kulandaivel, (2013). RSC Advances 3, 2369.

Pg Song, Zh Gao, Yz Cai. (2011). Fabrication of Exfoloated Grapgehe-based Polypropylene Nanocomposite with Enhanced Mechnical and Thermal Properties. Polymer.

Panchal Shivam.(2010). Recent Developments on biodegradable polymers and their future trends, Int. Res. Journal of Science & Engineering, 4(1): 17-26.

Peterson, John, Poddutori, Premaladha, Romark, Vladimir 2013. Mechanism For Production Of Biobased Products From Plant Lignin.

Pillai, P. K. S., Li, S., Bouzidi, L., & Narine, S. S. (2016). Metathesized palm oil polyol for the preparation of improved bio-based rigid and flexible polyurethane foams. Industrial Crops and Products, 83, 568–576.

Praptijanto, A., Agustian, E., Putrasari, Y., Sebayang, D., Rus, A. Z. M., Hasan, S., & Untoro, P. (2015). Sonochemistry approach to reducing biodiesel reaction time from Jatropha Curcas oil by clamp on tubular reactor. *Energy Procedia, 68,* 480–489.

Pothan, Laly A, Zachariah Oommen, and Sabu Thomas. 2003. “Dynamic Mechanical Analysis of Banana Fiber Reinforced Polyester Composites.” 63: 283–93.

Plyushch, A., Macutkevic, J., Kuzhir, P.P., Banys, J., Hierro, V., & Celzard, A. (2016). Dielectric properties and electrical conductivity of flat micronic graphite / polyurethane composites. Journal of Nanophotonics, 10, 13 pgs.

Qi, J., Xie, J., Hse, C. Y., & Shupe, T.F (2013). Analysis of Phyllostachys Pubescens Bamboo Residue for Liquefaction : Chemical Components, Infrared Spectroscopy, and Thermogravimetry. BioResurces, 8(4), 5644-5654.

Ramesh P Babu, Kevin O’Conner, Ramakrishna Seeram (2013) Current progress on bio-based polymers and their future trends.

Renyuan Qian, Yangsheng YU. (2009). Transition of Polymers from Rubbery Elastic State to Fluid State.

Ridha, M (2007) Mechanical and failure properties od rigid polyurethane foam under tension, PHD thesis.

Ribeiro Da Silva, V., Mosiewicki, M. A., Yoshida, M. I., Coelho Da Silva, M., Stefani, P. M., & Marcovich, N. E. (2013). Polyurethane Foams Based on Modified Tung Oil and Reinforced With Rice Husk Ash I; Synthesis and Physical Chemical Characteriztion. Polymer Testing, 32(2), 438-445.

Ronda, J.C., Lligadas, G., Galia, M., & Cadiz. V., (2011). Vegetable Oils as Platform Chemical for Polymer Synthesis. *European journal lipid science technology*. Vol 113, pp. 46-58.

Rojas, Mauricio (3 August 2007). "Assessing the Engine Performance of Palm Oil Biodiesel". *Biodiesel Magazine*. Archived from the original on 11 May 2013. Retrieved 25 February2013.

Royal Society of Chemistry, 2009. www.rsc.org.

Rupani, P., Ibrahim, M., & Ismail, S. (2013). Vermicomposting Biotechnology Recycling of Palm Oil Mill Wastes Into Valuable Products. International Journal Of Recycling Of Organic Waste In Agriculture, 2(1),10.

Rus, A. Z. M., Normunira, N., & Hassan, M. (2014). Thermal Characteristic of Biopolymer Foam using Hot Compression Technique, 8th MUCET, (November), 10–11.

Rus, A.Z.M (2010). Polymer from renewable materials. Science Polymer. Vol 93, pp. 1-16.

Rustu S. Kalyoncu, 2000. Graphite, U.S. Geological Survey Minerals Yearbook.

Saeed Kazemi-Najati, Karl R.Englund (2013). Effect of Highly Degraded High-Density Polyethlene (HDPE) on Processing and Mechanical Properties of Wood Lour-HDPE Composites. Vol.129.

Sattar, R., Kausar, A., & Siddiq, M. (2014). Advances in thermoplastic polyurethane composites reinforced with carbon nanotubes and carbon nanofibers: A review. Journal of Plastic Film and Sheeting, 31(2), 186-224.

S.Stankovich, Da Dikin, RD Piner. (2007). Synthesis of Graphene-Based Nanosheets Via Chemical Reduction of Exflated Graphite Oxide Carbon.

Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, and Bradley, D.C., eds., 2017, Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: U.S. Geological Survey Professional Paper 1802, 797 p.

S. Gayathir, P. Jayabal, M Kottaisamy and V. Ramakrishnan (2014). Synthesis of few layer grapheme by direct exfoliation of graphite and a Raman spectroscopic study. AIP Advances 4,027116

S. Rustu Kalyoncu.(2000). "A Complex Natural Resource, An Overview of Factors Affecting Coal Quality and used in The United States.

S.T.K. Bindu, A. B. Nair, B. T. Abraham, P.M. S. Beegum, E. T. Thachil, (2014). Polymer 55, 3614.

Saha BC (2003) Hemicellulose bioconversion. J Ind Microbiol Biotechnol 2003(30):279–2791

Salman Zafar (2018), Article of Bio-energy Development in Malaysia.

Samarth, N. B., & Mahanwar, P. a. (2015). Modified Vegetable Oil Based Additives as a Future Polymeric Material- Review. *Open Journal of Organic Polymer Materials, 5(January), 1-22.*

Sangeetha, N. J., Malar Retna, A., Jasmala Joy, Y., & Sophia, A. (2014). A review on advanced methods of polyurethane synthesis based on natural resources *Jcps, 7(3), 242-249.*

Sarani Zakaria (2003) Eco-product from lignocellulose biomass.

Shah, Bhavesh L, and Laurent M Matuana. 2004. "Online Measurement of Rheological Properties of PVC / Wood-Flour Composites *." 10(3): 121–28.

Shaharudin kormin, 2018. Polyurethane foam from oil palm fruit waste synthesis and characterization of biopolyol and foam properties. PHD Thesis.

Shammya Afroze, M. Mahbubur Rahman, Humayun Kabir, Md. Alang\mgir Kabir, Farid Ahmed, Md.Abdul Hossain, Md. Abdul Gafur (2012). Physical, optical and thermal properties of graphite and talc filler reinforced polypropylene (PP) composites.

Shaofeng Zhou, Qiaoxin Zhang, Chaoqun Wua, Jin Huang, 2013."Effect of carbon fiber reinforcement on the mechanical and tribological properties of polyamide6 / polyphenylene sulfide composites", Materials and Design, vol. 44, pp 493–499.

Shaffer. (2016) The Science and Design of Engineering Materials. Book 2nd Edition.
.

Shengjun Hu, M.S., (2013). Production and Characterization of Bio-based Polyols and Polyurethanes from Boidiesel-derived Crude Glycerol and Lignocellulosic Biomass 1-223.

Shammya Afroze, M. Mahbubur Rahman, Humayun Kabir, Md. Alamgir Kabir, Farid Ahmed, Md. Abdul Hossain, Md. Abdul Gafur (2012). Physical, Optical and Thermal Properties of Graphite and Talc Filler Reinforced Prolypropylene (PP) Composites. International Journal of Advanced Scientific and Technical Research. Issues 2 Volume 5, October .

Sridhar, V., Lee, I., Chun, H. H., & Park, H. (2013). Graphene reinforced biodegradable poly(3-hydroxybutyrate-co-4-hydroxybutyrate) nano-composites. *Express Polymer Letter*, 7(4), 320-328.

Siester H.W and Holland Moritz,K.(1980). Infrared and Raman spectroscopy of polymers, marcel Dekker.

Siquera, G, J, Dufresne, A (2010) Cellulosic bionanocomposites: A review of preparation properties and application. Polymers, 2,728-765.

Sites.google.com, (2014). Polystyrene (PS) - ISU MatE453/MSE 553 - Lab 3 - FTIR. [online]Available https://sites.google.com/site/isumate453lab3group8/data/polystyrene-ps [Accessed 29 Oct. 2014].

Sonjui, T., & Jiratumnukul, N. (2015). Physical properties of bio-based polyurethane foams from bio-based succinate polyols. Cellular Polymers, 34(6), 353–365.
Stuart B.H (2002). Polymer analysis.

Sung, G., Kim, S. K., Kim, J. W., & Kim, J. H. (2016). Effect of isocyanate molecular structures in fabricating flexible polyurethane foams on sound absorption behavior. *Polymer Testing, 53*,156–164.

Sulaiman, F.,Abdullah, N., Gerhauser, H., & Shariff. (2010). Rigid And Flexible Polyurethane Foams Production From Palm Oil-Based Polyol. Phd Thesis.

T. Skaltas, N. Karousis, H. J. Yan, C. R. Wang, S. Pispas, and N. Tagmatarchis, J. Mater. Chem. (2012). 22, 21507.

Technology, P. (2013) studies on polyurethane and its hybrid foams with micro and nano fillers for low frequency sound absorption.

Tensile Test of Polymers 2015. Budapest University Of Technology And Economics.Faculty Of Mechanical Engineering.Department Of Polymer Engineering.

Tensile testing, 2004.004 ASM International. All Rights Reserved.Tensile Testing, Second Edition (#05106G). www.asminternational.org

Thirumal, M., Khastgir, D., Singha, N.K, Manjunath, B.S. & Naik, Y. P. (2008). Effect of Foam Density on the Properties of Water Blown Rigid Polyurethane Foam *Journal of Applied Polymer Science*. Vol. 108, pp. 1810–1817.

Tingting Qu, Wanjun Guo, Laihong Shen, Jun Xiao, and Kun Zhao (2011). Experimental Study of Biomass Pyrolysis Based on Three Major

Components: Hemicellulose, Cellulose, and Lignin. 50(18), pp 10424-1043.

Usman, M. A., Adeosun, S. O. & Osifeso, G.O. (2012). Optimum Calcium Carbonate Filler Concentration for Flexible Polyurethane Foam Composite. *Journal of Minerals & Materials Characterization & Engineering*, Vol. 11, No.3, pp.311-320.

Uzoh, C.F., Onukwuli, O. D., Odera, R. S., & Ofochebe, S. (2013). Optimization of polyesterification process for production of palm oil modified alkyd resin using response surface methodology. Journal of envirenment chemical engineering (4), 777-785.

Vakili, Rafatullah, Zuhairi, Hakimi Ibrahim, babak Salamatinia, Zahra Gholami (2014). Oil Palm Biomass As An Adsorbent For Heavy Metals.

Walker GM (2010) Bioethanol: science and technology of fuel alcohol. Ventus Publishing ApS. ISBN 978-87-7681-681-0.

Wang, R., & Schuman, T.P (2012). Vegetable oil-derived epoxy monomers and polymer blends: A comparative study with review. Express polymer letters with review.

Wei, N (2013). Modification and characterization of liquefied biomass-based epoxy resin. Master thesis.

William B. Jensen (2008) Jounal of Chemical Education :The Origin Of The Polymer Concept, 85(5), 624.

William Boyes, Stiven Foster, Martin Gehlhaus, Karen Hogan, Allan Marcus, Peter McClure, Mark Osier, Andrew Roonet (2005). EPA Journal "Toxicological Review of Toluene" In Support of Summary Information on the Integrated Risk Information System (IRIS).

Wu, H., Wu, S., Wu, I. and Chang, F. (2001). Novel determination of the crystallinity of syndiotactic polystyrene using FTIR spectrum. Polymer, 42(10), pp.4719--4725.

Wu, G., Xu, X., He, X., & Yan, Y. (2018). Preparation and Characterization of Graphene Oxide-Modified Sapium Sebiferum Oil-Based Polyurethane Composites with Improved Thermal and Mechanical Properties, Polymers 10(133).

Wypych, George. 2016. ―Handbook of fillers‖. Elsevier.

Xue, B.L., Wen, J.L., Xu, F., R.c., (2013). Polyols Production by Chemical Modification of Autocatalyzed Ethanol-Water Lignin From Betula Alnoides. *Journal of Applied Polymer Science*, *129, 434-442.*

Xie, Meiju, Xiaolong Liu, and Huilin Li. 2005. "Influence of Poly (Ethylene Glycol) -Containing Additives on Extrusion of Ultrahigh Molecular Weight Polyethylene /Polypropylene Blend."

Yang, Yiqi, Reddy, Narendra, Hu, Chunyang, Enqi, Jin 2013. Thermoplastics from distillers dried grains and feathers.

Zarina, Y., Mustafa Al Bakri , A. M., Kamarudin, H., Nizar, I. K., & Rafiza, A. R. (2013). Review on the various ash from palm oil waste as geopolymer material. Reviews on Advanced Material Science, 34(1), 37-43.

Zhang, B. (2014) Development of bio-based Phenol Formaldehyde novolac resins using mountain pine beetle infested lodgepole pine barks. Master thesis.

Zhang, C; Li, J; Hu, Z; Zhu, F; Huang, Y. (2012). Correlation netween the acoustic and porous cell morphology of polyurethane foam: Effect of interconnected porosity. *Materials and design; 41,319-325.*

Zhang, Q., Zhang, G., Xu, J., Gao, C., & Wu, Y. (2015). Recent advanced on ligin-derived polyurethane polymers. *Reviews and Advanced Material Science, 40(2), 146-154.*

Zhang, C., Garrison , T. F., Madbouly, S. A., & Kessler, M. R. (2017) Progress in Polymer Science Recent advance in vegetable oil-based polymers and their composites. Progress in Polymer Science, 71, 91-143.

Zhao, J.; Lu, L.; Rabczuk, T. The tensile and shear failure behavior dependence on chain length and temperature in amorphous polymers. Comput. Mater. Sci. 2014, 96, 567–572.

Zhao, J.; Nagao, S.; Zhang, Z. Thermomechanical properties dependence on chain length in bulk polyethylene: Coarse-grained molecular dynamics simulations. J. Mater. Res. 2010, 25, 537–544.